

# **THERMAL CONDUCTIVITY - TCON**

## **Introduction**

Thermal conductivity is a measure of the rate that heat flows through material. In marine geophysics, thermal conductivity profiles of sediment and rock sections are used with temperature measurements to determine heat flow. Heat flow is not only characteristic of the material, but an indicator of type and age of ocean crust and fluid circulation processes at shallow and great depths.

Thermal conductivity can be measured by heating a material with a known heating source and measuring the temperature change with time. Conductivity values are reported in *Watts / meter \* degrees Kelvin*. Prior to Leg 109, conductivity was reported in *cal\*10<sup>-3</sup>/cm-sec-deg*, but was converted to *[W/m \* K]* before entry into an S1032 database. During the Ocean Drilling Program (ODP), almost 37,000 individual measurements were collected on 104 of the 110 legs.

## **Data Acquisition**

Thermal Conductivity (TCON) measurements were done on both whole cores and split cores. Soft and semi-indurated sediments were usually analyzed as whole cores. Hard rocks were often measured after splitting. The sections were allowed to equilibrate after they were brought to the laboratory. TCON measurements were made after the sections were run through the MultiSensor Track. Small holes were drilled through the core liner to allow the full-space probes to be inserted. If the sediment was semi-consolidated, the hole was drilled into the sediment with thermal joint compound applied to ensure good contact between the probe and the sediments. For hard rock measurements, a smooth surface was prepared on a split-core specimen at least 5 cm long.

The first system used for TCON measurements was the Thermcon-85 built by Woods Hole Oceanographic Institution. Initially, data were collected using a DEC PRO-350. Up to five needles could be connected to the system at one time: one needle was inserted into a standard material for a control measurement and the rest of the needles were inserted into the cored material. The processed results were logged on logsheets and entered into an S1032 database. A new PC-based program was deployed on Leg 129 that allowed the operator to control the measurements, process the raw data and write the results to a file. The needles had to be calibrated periodically using standard materials of known thermal conductivity. The calibration data were analyzed by linear least squares and the coefficients were stored in a file that the program accessed during analysis. The Thermcon-85 was operational for the entire ODP, though it was not used much after Leg 168 when the Teka TK04 system was deployed.

The Teka TK04 system was more automated than the Thermcon-85 system. It provided automated calibration, drift and measurement features, full-space and half-space needles, and processing and graphing of results. Multiple measurements could be taken under identical conditions. Optional files could be created in addition to the file with the results. Those files contained the measurement parameters, raw data (temperature – time series), evaluation parameters and all valid calculated thermal conductivity values.

Additional information about ODP thermal conductivity measurements can be found in *Technical Note 26: Physical Properties Handbook*, Chapter 8.

## Archive

### Pre-Janus Archive

Early in the ODP, TCON data were collected on logsheets which were sent back to ODP/TAMU at the end of each cruise. The data were entered into an S1032 database and the logsheets were microfilmed for archival storage. TCON data were stored in the S1032 database through Leg 128. A new PC-based program was deployed on Leg 129 which created files that were brought back and archived on the ODP/TAMU servers.

### Migration of TCON data to Janus

The data model for Thermal Conductivity data can be found in Appendix I. Included are the relational diagram and the list of the tables that contain data pertinent to TCON analyses, the column names and the definition of each column attribute. ODP Information Services Database Group was responsible for the migration of pre-Leg 171 data to Janus.

The thermal conductivity tables were yet not finalized when Janus became operational on Leg 171. After discussions about how to implement the TCON part of the database, it was decided to save only the calculated thermal conductivity measurements. Since the raw data collected on the two systems were different, the implementation of storing raw data in the database was deferred and not completed during the ODP. Raw data are still archived on IODP/TAMU servers and can be requested through the IODP Data Librarian [ [database@iodp.tamu.edu](mailto:database@iodp.tamu.edu) ].

### Janus Thermal Conductivity Data Format

TCON analyses can be retrieved from Janus Web using a predefined query. The Thermal Conductivity query webpage allows the user to extract data using the following variables to restrict the amount of data retrieved: leg, site, hole, core, section, probe number, depth, or latitude and longitude ranges. TCON analyses made with the TK04 system often produce multiple measurements at the same interval. It became a

common practice to put the individual measurement values in the *Comments* field and the average was stored in the *Thermcon\_value* field.

Table 1 contains the data fields retrieved from the Janus database using the Janus Web predefined query. The first column contains the data item; the second column indicates the Janus table or tables in which the data were stored; the third column is the Jnauis column name or the calculations used to produce the value. Appendix II contains additional information about the fields retrieved using the Janus Web Thermal Conductivity query, and the data format for the archived ASCII files.

Table 1. Thermal Conductivity query

| Item Name         | Janus Table               | Janus Column Name                                      |
|-------------------|---------------------------|--|
| Leg               | SECTION                   | Leg  |
| Site              | SECTION                   | Site   |
| Hole              | SECTION                   | Hole   |
| Core              | SECTION                   | Core   |
| Coretype          | SECTION                   | Core_type  |
| Section           | SECTION                   | Section_number   |
| Top (cm)          | TCON_DATA                 | PP_top_interval  |
| Bottom (cm)       | TCON_DATA                 | PP-bottom_Interval                                     |
| Depth (mbsf)      | DEPTH_MAP,<br>TCON_DATA   | DEPTH_MAP.Map_interval_top +<br>TCON_DATA.Top_interval |
| Probe Type        | TCON_DATA                 | TCON_probe_half_full                                   |
| Thermcon Value    | TCON_DATA                 | TCON_proc_thermcon                                     |
| Ship Equipment Id | TCON_DATA,<br>SYSTEM_TYPE | System_id  |
| TCON Probe Num    | TCON_DATA                 | TCON_prrobe_num  |
| Comments          | TCON_DATA                 | Comments   |

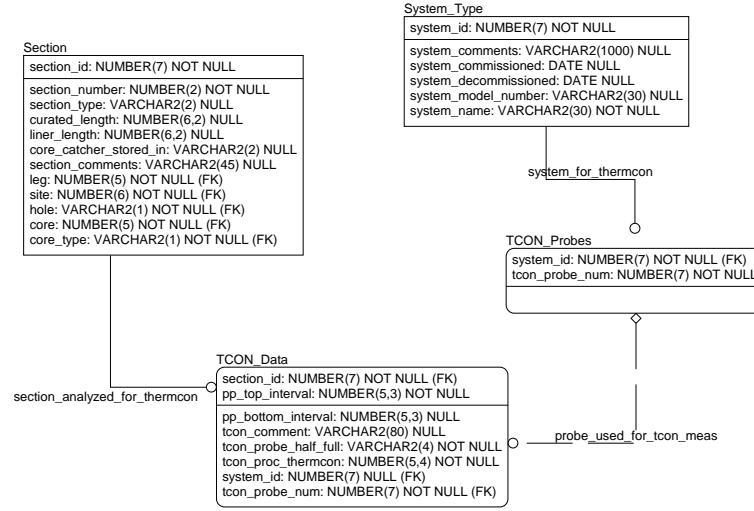
## Data Quality

The TCON dataset is one of the more complete data sets collected by the ODP. A common error found during migration falls in the generic category of operator error. Analytical results were written on logsheets. These data were then typed into S1032. The data acquisition programs required manual entry. Mistakes in logging intervals, logging data, typing data into the database, etc. occasionally happen, and were not always identified. Often, the scientific party found errors and corrected them for the data included in the Initial Report volume, but data sent back to ODP/TAMU did not get corrected.

Most data collected after the Janus database was operational on Leg 171 were verified as part of the Janus data management and verification procedures (see Metadata Introduction). Some verification was done on the pre-Leg 171 data; however, if there is a discrepancy between the database and data in the Initial Report volumes, the published data should be considered more reliable.

## **Reference**

Blum, P., 1997, Physical Properties Handbook: A guide to the shipboard measurement of physical properties of deep-sea cores, ODP Tech. Note 26.



## APPENDIX I: Janus Data Model – Thermal Conductivity

| Thermal Conductivity - TCON |                      |  |
|-----------------------------|----------------------|--|
| Table Name                  | Column Name          | Column Comment   |
| TCON_Data                   | section_id           | Unique Oracle-generated sequence number to identify each section.  |
|                             | pp_top_interval      | The top interval of a measurement in meters measured from the top of a section.                          |
|                             | pp_bottom_interval   | The bottom interval of a measurement in meters measured from the top of a section.                       |
|                             | tcon_comment         | Comment recovered from measurement data files.   |
|                             | tcon_probe_half_full | Type of needle probe: FULL - insertion into soft material; or HALF - contact with flat surface.          |
|                             | tcon_proc_thermcon   | Calculated thermal conductivity value, corrected using residual drift at end of drift study, in W/m * K. |
|                             | system_id            | Unique identifier for a system of equipment used to collect data.  |
|                             | tcon_probe_num       | Unique number that identifies a probe.   |

|             |                |   |
|-------------|----------------|---|
| TCON_Probes | system_id      | Unique identifier for a system of equipment used to collect data.   |
|             | tcon_probe_num | Unique number that identifies a probe, e.g. 330, 352, 19608. This number is used internally by the instrument to associate measurements with the manufacturer's specifications for the probe. |

|         |                        |   |
|---------|------------------------|---|
| Section | section_id             | Unique Oracle-generated sequence number to identify each section. This is done because of the physical subsection / zero section problems. In adding new sections, deleting sections or changing sections - don't want to have to renumber. |
|         | leg                    | Number identifying the cruise for which data were entered into the database.  |
|         | site                   | Number identifying the site from which the core was retrieved. A site is the position of a beacon around which holes are drilled.   |
|         | hole                   | Letter identifying the hole at a site from which a core was retrieved or data were collected.   |
|         | core                   | Sequential numbers identifying the cores retrieved from a particular hole. Cores are generally 9.5 meters in length, and are numbered serially from the top of the hole downward.   |
|         | core_type              | A letter code identifying the drill bit/coring method used to retrieve the core.  |
|         | section_number         | Cores are cut into 1.5 m sections. Sections are numbered serially, with Section 1 at the top of the core.   |
|         | section_type           | Used to differentiate sections of core (S) from core catchers (C). Previously core catchers were stored as section CC, but in Janus core catchers are given the next sequential number from the last section recovered.                     |
|         | curated_length         | The length of the section core material, in meters. This may be different than the liner length for the same section. Hard rock cores will often have spacers added to prevent rock pieces from damaging each other.                        |
|         | liner_length           | The original length of core material in the section, in meters. Sum of liner lengths of all the sections of a core equals core recovery.  |
|         | core_catcher_stored_in | Sometimes the core catcher is stored in a D tube with a section. core_catcher_stored_in contains the section number of the D tube that holds the core catcher.  |
|         | section_comments       | Comments on this section.   |

|             |                       |   |
|-------------|-----------------------|---|
| System_Type | system_id             | Unique identifier for a system of equipment used to collect data.                   |
|             | system_comments       | Comments associated with a piece of analytical equipment.                           |
|             | system_commissioned   | Date that a piece of equipment was deployed to collect scientific data for the ODP. |
|             | system_decommissioned | Date that a piece of analytical equipment was no longer used by the ODP.            |
|             | system_model_number   | The model number of an piece of equipment used for scientific analysis.             |
|             | system_name           | The name for a piece of equipment used for analysis.                                |

## Appendix II. Description of data items from Thermal Conductivity query

| Item Name         | Column Description   | Format              |
|-------------------|--|---------------------|
| Leg               | Number identifying the cruise. The ODP started numbering the scientific cruises of the <i>JR</i> at Leg 101. A leg was nominally two months duration. During the 18+ years of the ODP, there were 110 cruises on the <i>JR</i> .   | Integer 3           |
| Site              | Number identifying the site. A site is the location where one or more holes were drilled while the ship was positioned over a single acoustic beacon. The <i>JR</i> visited 656 unique sites during the course of the ODP. Some sites were visited multiple times, including some sites originally visited during the Deep Sea Drilling Program for a total of 673 site visits.  | Integer 4           |
| Hole              | Letter identifying the hole. Multiple holes could be drilled at a single site by pulling the drill pipe above the seafloor, moving the ship some distance away and drilling another hole. The first hole was designated 'A' and additional holes proceeded alphabetically at a given site. Location information for the cruise was determined by hole latitude and longitude. During ODP, there were 1818 holes drilled or deepened. | Text 1              |
| Core              | Cores are numbered serially from the top of the hole downward. Cored intervals are up to 9.7 m long, the maximum length of the core barrel. Recovered material was placed at the top of the cored interval, even when recovery was less than 100%. More than 220 km of core were recovered by the ODP.   | Integer 3           |
| Coretype          | All cores are tagged by a letter code that identifies the coring method used.  | Text 1              |
| Section           | Cores are cut into 1.5 m sections in order to make them easier to handle. Sections are numbered serially, with Section 1 at the top of the core. TCON measurements were made at discrete locations on the sections. Core Catcher sections identified as "CC."  | Integer 2 or Text 2 |
| Top (cm)          | The top interval of a measurement in centimeters measured from the top of a section.   | Decimal F4.1        |
| Bottom (cm)       | The location of the bottom of a sample in centimeters measured from the top of a section.  | Decimal F4.1        |
| Depth (mbsf)      | Distance in meters from the seafloor to the sample location.   | Decimal F7.3        |
| Probe Type        | Type of needle probe:<br>FULL - insertion into soft material; or<br>HALF - contact with flat surface..   | Text 4              |
| Thermcon Value    | Final conductivity value in Watts/meter * degrees Kelvin.  | Decimal F 5.4       |
| Ship Equipment Id | Number identifying the system used to collect data. Valid values:<br>3 -- Teka TK04<br>4 -- Thermcon-85  | Integer 7           |
| TCON Probe Num    | Unique number that identifies a probe, e.g. 330, 352, 19608. This number is used internally by the instrument to associate measurements with the manufacturer's specifications for the probe   | Integer 7           |
| Comments          | Comments or remarks about the Thermal Conductivity test or data. Listing of Individual measurements taken at the same location (Thermcon_value contains the average.)  | Text 80             |